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AUTHOR Nuthall, Graham
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ABSTRACT

A study of students' thinking processes during their engagement in classroom tasks in science and social studies units in upper elementary school classrooms was conducted as part of a series of studies on learning. As a result of previous studies, a theory of the learning process has been developed. A central component of the theory is the long-term working memory through which students process and integrate new experiences with previous knowledge. Students in two classrooms, each containing fifth and sixth graders, participated. Selected students (n=16) were interviewed after the thinking tasks (an average of 20 days later), using video recordings to stimulate their memories. The open-ended interviews combined with video-clips was a successful approach. About 36% of student responses described something about their thinking processes, but most of the content of these responses was closely related to behaviors and perceptions. The overall impression from the interviews was that students were focused primarily on getting the task done. How these findings relate to the proposed model of long-term working memory is not yet clear, but further studies will explore how students experience and understand their involvement in classroom activities. An appendix describes types of student responses to the videos. (Contains 2 figures, 3 tables, and 33 references.) (SLD)

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How students learn: The validation of a model of knowledge acquisition using stimulated recall of the learning process.

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Graham Nuthall
Education Department
University of Canterbury
Christchurch
New Zealand (Aotearoa)

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This paper reports the analysis of data from the **Project on Learning** at the University of Canterbury. This Project has been funded by a three-year grant from the Marsden Fund . The technical expertise required for creating and maintaining the recording equipment has been provided by **Roger Corbett**. **Anthea Clibborn-Brown** has managed the day to day running of the Project and assisted with observing in classrooms and transcribing interviews.

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The purpose of this paper is to report the results of a study of students' thinking processes during their engagement in classroom tasks in typical science and social studies units in upper elementary school classrooms. This study is part of a larger series of studies of how students learn and acquire knowledge from their classroom experiences (Alton-Lee & Nuthall, 1990; Alton-Lee, Nuthall & Patrick, 1993; Nuthall & Alton-Lee, 1992, 1993; Nuthall, 1999; Nuthall, in press, a, in press, b).

In previous studies we have explored individual students experiences in elementary and middle school classrooms using audio- and video-recordings and direct observations. From the results of early studies, we developed a set of principles for predicting what students will and will not learn from their involvement in classroom activities. These principles take into account the type and relevance of the information contained in each experience, the timing of the experiences relative to each other, and the sequence in which they occur (Nuthall, 1999). The validity of these principles has been assessed by applying them to data on individual student experience from further studies and using them to predict with 80-85% success exactly which propositions, concepts, and principles, the students learned and did not learn (Nuthall & Alton-Lee, 1992, 1993).

A theory has been developed from these principles that attempts to explain how the learning process occurs. The major structural elements of this theory are illustrated in the model depicted in Figure 1.

Include Figure 1 about here

A central component in this theory is the long-term working memory through which students process and integrate their new experiences with their previous knowledge and beliefs to create new knowledge constructs that become part of their long-term memory. This working memory is depicted as both part of, and separate from, the social and academic tasks and processes that constitute life in classrooms.

In previous reports (Nuthall, in press, b) I have argued that the processes that go on in long-term working memory and determine how experience becomes knowledge are internalised versions of the sociocultural activities that students participate in. The model presumes that the external world of participation in classroom activities and the

internal world of cognitive processing are in a continuous transactional relationship with each other. While it is possible to distinguish the social from the cognitive, and the external world of classroom activities from the internal world of students' minds, these distinctions have little significance in the students' experiences and in the learning that arises from those experiences.

The evidence from classroom observations, recordings and interviews suggests that there are five distinguishable socio-cognitive activities or processes involved in the acquisition of knowledge and beliefs. These are:

1. Acquiring and clarifying information.
2. Creating associative links with related knowledge and experience.
3. Elaborating and integrating the content of experiences.
4. Evaluating the truth and consistency of information.
5. Metacognitive monitoring of the cognitive processes.

These activities/processes are not sharply defined because they do not occur independently of each other. Nor is the set of five likely to be totally inclusive. They are, however, comprehensive and general enough to suggest that, taken together, they constitute the underlying activities/processes by which students construct the coherent elaborated networks of knowledge and experience that characterise their learning in typical science and social studies units.

The evidence for these activities/processes is indirect and partial. We have used evidence from students' recollections of their learning and memory processes (Nuthall, 1996a; Nuthall & Alton-Lee, 1995), observations of their activities during events that are critical to the learning process, and recordings of their self-talk and private interactions with peers (Nuthall, 1999, in press, a). In order to get a more direct and detailed picture of the learning process that we believe takes place in the long-term working memory, we decided to make use of the stimulated-recall technique. Students were asked to recall their experiences and thoughts while they watched video-clips of their involvement in events and activities that appeared, on the basis of our model, to be critical to their learning of specific concepts or propositions.

Research using stimulated recall with audio and video recordings.

The use of audio and video recordings to stimulate recall of cognitive processes in the classroom has been reported in a number of studies. The

early classic study was reported by Bloom (1953) and dates back to the time when audio-recording first became widely available. In Bloom's original study, students listened to audio-recordings of a lecture and of the discussion in small groups in which they had participated. As they listened, the recording was stopped and the students asked to recall what they had been thinking at the time. Bloom used the data from these interviews to show that, compared with listening to a lecture, participating in small group discussion resulted in less irrelevant and tangential thoughts, and in less passive thinking ("simple comprehension"). He also noted that recall of what happened in a lecture or group discussion was 95% accurate if the recording was heard two days after the event, and dropped to 65% accuracy up to two weeks later. Bloom also noted that:

> ... students do not report all their thoughts; frequently they select and report the thoughts they believe most relevant, or they tend to characterize their thoughts rather report them as they occurred. (Bloom, 1953, p.16)

Since Bloom's study, audio and video-cued recall of thought processes has been used in studies of both students' and teachers' thinking and use of cognitive and metacognitive strategies in classrooms (e.g., Edwards & Marland, 1982, 1984; Kagan, Krathwohl, Goldberg, & Campbell, 1967; Morine & Vallance, 1975).

Peterson, Swing, Braverman, & Russ (1982) reported a study of the thought processes of 5th and 6th grade students during math lessons. Students viewed 5 segments from each of two specially staged direct instruction lessons on successive days. They were interviewed individually on what they had been thinking during each segment.

The students responses during these interviews were coded using a hierarchy of categories from 'not attending' through 'understanding' to recall of specific cognitive strategies. Responses in which a student referred in general to thinking, listening, or working, were coded as a reference to a "general cognitive strategy". Responses in which a student reported a more specific cognitive strategy such as "repeating something to oneself", "checking one's answer", "reworking a problem" were coded as specific cognitive strategies. The two most common specific cognitive strategies were "trying to understand the teacher or problem", and "relating the information to prior knowledge" (Peterson, et al., 1982, p. 544).

The results reported by Peterson and her colleagues showed that students reported an average of about 1.6 different specific cognitive strategies per video-taped segment. The frequency with which specific

cognitive strategies were reported related to student ability (higher ability students reported more specific strategies) and to student achievement. However, when ability was partialed out, the relationship between strategy use and achievement disappeared. The one exception was when the students reported using a specific cognitive strategy to try to understand a problem. This correlated with achievement when ability was partialed out. The authors concluded:

> According to student responses to the stimulated-recall interview, the picture that emerges is that higher ability students are more inclined to attend to the lesson, either to employ a variety of specific cognitive strategies or to engage in these processes more frequently ... (Peterson, et al., 1982, p. 545)

Since the use of specific cognitive strategies was related to both higher achievement and higher levels of academic ability, the authors suggest that, in the context of specific classroom activities, cognitive strategies may be the means by which ability is translated into achievement.

The study reported by Edwards and Marland (1982, 1984) was more informal and involved four students who were specially selected for their ability to express ideas clearly and to talk about their thoughts. Three biology lessons were videotaped on three mornings and the students interviewed on the same afternoons.

Edwards and Marland's results suggested that students' thinking was focused on curriculum relevant classroom events from 25 - 60% of the time, and the times when they were focused on classroom events were rarely the same for the four students. The number of different thinking strategies identified by the students varied from 6 to 20. The list of strategies identified by one student included formulating and evaluating answers to the teacher's questions, analyzing and organising resources for solving problems, managing interactions with peers and with the teacher. The authors were surprised at the frequency with which the students interacted with their peers even in teacher-led whole class discussions.

The study reported by Anthony (1994) provides a much richer picture of the ways in which students can report their cognitive strategies during classroom lessons. She used videotaped segments of weekly mathematics lessons and interviewed students, asking them to "view the segments of the lesson and relive, as fully as possible, the classroom situation" (Anthony, 1994, p.128).

Anthony classified the students responses into four general categories of reported strategies: cognitive, metacognitive, affective, and resource

management. The cognitive strategies she divided up into three categories: rehearsal (e.g., "I'm trying out answers again") elaboration (e.g., "I thought of the size of somebody's shirt") and organisation (e.g., "I understand it but I know I won't remember it, so I write it down"). The elaboration category also included linking to previous knowledge, creating an image in the mind, making links between different parts of the lesson. She also noted that students sometimes reported that they were not thinking at all (e.g., "I'm just looking, not really thinking about anything") or that they were doing things to relieve or divert boredom.

Anthony reached two interesting conclusions. First she noted that verbal reports of thinking processes may be limited for a number of reasons.

> It is probable that many more strategies were employed but not revealed due to either the students' automaticity of strategy use, inability to verbalise a strategy, or perhaps a decision that it was not important enough to mention. (Anthony, 1994, p. 137)

Second she noted that students appeared to equate learning to "being taught", that is, to doing exactly what the teacher and/or the textbook instructed them to do. The consequence of this view was that mathematics was seen as simply a sequence of tasks or problems that had to be completed. The focus of attention became resource management in the interests of completing set tasks. The strategies that students reported (especially lower achieving students) were mostly task completion strategies rather than self-consciously "learning" focused strategies.

The validity of video-cued recall of thinking processes

Most of those reporting the use of video-recordings to stimulate recall of thought processes have discussed the problems of the reliability and validity of the procedures they used (e.g. Anthony, 1994; Garner, 1988; Marland, 1984; Peterson, et al., 1982). The primary concern has been with whether thinking processes are something that a person is, or can be aware of, and whether an awareness of them can be stored in memory and recalled in the same way as one's perceptions of the external world and personal behaviours can be recalled. In a much quoted paper, Nisbett and Wilson (1977) have argued that we are not normally aware of our thought processes. What we report when we are asked to report on thinking processes is the kind of account that we have been led to believe is expected in such circumstances. As part of their evidence, Nisbett and Wilson quote close similarities between personal reports of mental processes and reports that

people were asked to create about how they thought other people would think in similar circumstances. Subsequently, Ericsson and Simon (1980, 1984) have argued for the value of self-report data, but in carefully managed circumstances and for a limited range of specific purposes.

One of the problems with the research in this area is a failure to distinguish between cognitive strategies and cognitive processes. For example, in her paradigm case of the use of a cognitive strategy, Garner describes a person who selectively re-reads a text and writes a summary of its main points (Garner, 1984, 1990). Selective re-reading and writing are both in large part observable behaviors that could be, in principle, recorded by an external observer. Edwards and Marland (1982, 1984) in their list of the learning strategies reported by one of the students they interviewed included "arranges with neighbour for both to raise hand to attract teacher's attention" alongside "uses logical approach in problem solving". Most researchers appear to include anything that students reported in response to the researchers' interview questions regardless of whether the reported activity was a primarily cognitive or "thinking" process, or a primarily behavioral or observable process. Yet most of the discussions of the validity of the stimulated-recall and interview techniques used in these studies focus on the students' awareness of mental processes and ability to recall essentially private experiences (cf. Garner, 1988).

Underlying this confusion is a commonly held view of the relationship of mental processes to observable behaviors. The studies reported by Peterson and her colleagues, Edwards and Marland, and Anthony, all seem to take as their starting point the mediational paradigm of classroom learning. In this paradigm, often attributed to Doyle (1977), teacher behaviors lead to student learning via "implicit human processes that mediate between instructional stimuli and learning outcomes" Peterson, et al., 1982, p. 536). Whether intended or not, a sharp distinction is made in the theory between observable behaviors and mental or cognitive processes that is not translated either into a similarly clear distinction in the classroom data, or into an argument that justifies ignoring such a distinction.

Several researchers, following Bloom, have made the point that students reports of their own thinking processes are probably not complete. In addition to the usual concerns about students trying to say what the interviewer wanted, Anthony notes that some may not be reported because of their "automaticity". Her comment is consistent with the view that people are not always and continuously aware of their cognitive processes. If

Nisbett and Wilson's claims of complete unawareness are treated as only relevant to a limited set of circumstances, and Ericcson and Simon's position of limited awareness is taken as more appropriate to classroom research, there still remains the problem of deciding what cognitive processes one can expect young students to be aware of, and in what circumstances they might not only be aware of them but also able to recall them.

Two pieces of evidence indicate where the solution might be found. When Edwards and Marland asked their students to comment on the validity of their interviews, one of the students said:

> Well I don't think you think about thinking normally. You only think about thinking when you're trying to. ... Because to just think naturally and remember it, no one does that I don't think, or no one that I know ... (Edwards & Marland, 1982, p.40.)

This would seem to suggest that, as a number of philosophers of mind have claimed (e.g., Crick, 1994; Dennett, 1991), we are normally unaware of mental processes because they are not distinct processes that occur independently of our actions. Thinking is in the doing and it requires something unusual for us to become aware of thinking as something distinct from out actions.

There are two occasions when people seem most aware of their mental processes. One is when there are alternative courses of action that might be taken. Choice and/or planning are required and we become aware of the considerations involved in making a decision. The second is when the usual ways of acting in a situation strike difficulties and awareness of the problem is needed in order to solve it.

In Peterson et al.'s study, the two specific cognitive strategies students reported that did relate to achievement were associated with students having problems. The example of "relating to prior knowledge" that the authors cite was about a student trying to recall which was the denominator and which was the numerator ("Well, I was thinking about, you know, I was trying to remember stuff from last year that I was taught and, you know, numerator and denominator, which was which, and stuff like that."). The other category (trying to understand) implies some kind of difficulty or need to find alternative or supplementary ways to comprehend what the teacher or text was saying.

They also reported that lower ability students were less likely to report the use of specific cognitive strategies. Perhaps lower ability students are less likely to be aware that they have a problem, or are less likely to have

available alternative methods or resources that they need to select to solve the problem. One of the lower ability students that we interviewed in this study described this lack of awareness of relevant knowledge when he was asked to answer a question or solve a problem in class. For him awareness came later, often not till he was in bed at night.

J Well um, takes quite a while. ... I try to get something out of my brain that I've learned. Like I've got all these like, just my cells but they have real thick doors and they take ages to open up and get stuff, stuff I think out of my mind, but I can do it by thinking hard about it.

I By thinking hard. Yes. Then you finally get the things .. ?

J Like with some stuff I thought I knew, and like, ... I've got stuff in my mind and I, it opens up when I'm asleep in bed and stuff and I remember that I should have said that. Or when we finish and I go and sat on the mat [in the classroom] and after we're doing something, and I remember again what it is.

Taken together, this evidence suggests that, for younger students, awareness of cognitive processes is not likely to be common, especially for students who are of lower ability and less likely to be either aware of problems or have available the knowledge or resources that need to organised to solve the problems.

There are now a considerable number of researchers as well as philosophers who do not accept a simple dichotomy between thinking processes and material actions (see for example, Cobb, & Yackel, 1996; Lave, 1991; Rogoff, 1995; Salomon, 1993). In previous reports, I have reviewed these ideas and set out a position based on a "transactional" relationship between students' cognitive processes, private interactions with peers and resources, and public interactions with the teacher (Nuthall, in press, a; in press, b). If such a transactional relationship exists between the inner (cognitive) world of the individual student and the external (sociocultural) world of the student's interactions with teacher, resources, and other students, then students' reports of their experiences should also not contain clear distinctions between their actions, their perceptions and their thoughts. For this reason, the data analysis reported below is both an exploration of what students say about their thought processes in the classroom and of its implications for understanding the relationship between cognition and behavior in the classroom.

Methods and Data Sources

This studies reported in this paper were carried out in the classrooms of two teachers in the same elementary school. Each taught a class that included both Year 5 and Year 6 (Grade 4 and 5) students. In the initial planning stage it was explained to the teachers that the purpose of the studies was to understand how students learned from their experiences in typical science and social studies units. They were asked to try to organise and run their classrooms in their usual way.

It was the standard practice in this school for these two teachers to plan units in science and social studies together, and to share the same resources. Because these units were already partly planned, we followed the teachers' suggestion that we observe the students during a social studies unit on Ancient Egypt and a science unit on the Nature of Light. In both classes, the social studies units were taught first and the science unit about two months later. One teacher (W) taught each unit before the other teacher (C) (see Figure 2).

Include Figure 2 about here

Both the science and the social studies units involved whole class, group, and individual activities. In the social studies units, the whole class activities included teacher-led discussions, the teacher reading a story, and students reporting back the results of individual and group activities. Group activities included creating a time line, reporting and discussing the results of student research and construction activities. Individual tasks included completing worksheets, drawing pictures for a mural, and constructing a miniature panorama or mobile. In the science units, the whole class activities included teacher demonstrations of light experiments, teacher-led discussions of the results of group and individual experiments. The group activities included a series of experiments with light using mirrors, prisms, lens, coloured cellophane and containers of water. Almost all the individual activities involved writing reports of group experiments and preparing a project book that recorded all that the students did in the unit.

Both of the teachers arranged their rooms so that there was a carpeted space where the children could sit on the floor around the teacher for whole-class discussions. Desks were arranged in groups of 4-5 so that students could work together in groups on experiments. There were also other spaces where students could look through collections of relevant

books, and cut and paste construction materials. In both the social studies and science units, there were wall displays containing pictures and diagrams relevant to the topic and as the units progressed, murals created from the students' own work.

Although the teachers intended to use the same resources and follow the same format, there were significant variations in both the content and the time taken. Table 1 lists the number of days and the total time taken for each unit in each class. In that table, the studies have been code-named W7, C8, W9, and C10. The letter represents the name of the teacher and the number indicates the order in which the units were taught.

Include Table 1 about here

The design of each study

The design of each of these studies followed the design we have used in our previous studies, without (as yet) the long-term follow-up. The design involved the following steps:

1. Unit planning and test development: The author sat in with the two teachers when they were planning each unit and identified from their discussions and planning documents, the expected and possible learning outcomes for the unit. A written test for each unit was developed from the interviews with the teachers, and from an analysis of all the resources to be used in the unit. The test items were primarily multiple-choice and short written answer, often using diagrams and pictures taken from resource materials used in the unit. Also at this time, material was sent to parents about the project and parent permission obtained.

2. Familiarisation and training: Prior to each unit, recording equipment was set up and trialled in the classroom. The author and another observer (who had been trained in our previous studies) spent time in the classroom familiarising themselves with the students and the way the classroom worked. During this time the purpose of the recording equipment and the observers was explained to the students, and both teacher and students became familiar with the presence of the observers and the recording equipment in the classroom.

3. Student selection: Standardised test scores, and other relevant information about all the students in the class was obtained from the teacher. For each unit, 4 students were randomly selected within categories representing differences in ability, gender, and ethnic origin. Students

who, according to the teacher, had significant behavior problems or learning disabilities, or were experiencing significant stress, were not included. The experiences of these selected students were continuously observed and recorded throughout the unit. Their identities were not known to the students or the teacher until after the unit. The characteristics of the selected students are listed in Table 1.

4. Pre-tests: The outcome tests were administered about 7-8 days before each unit. The tests were read aloud by the author to the students to ensure attention to all relevant aspects of the items and to monitor the students involvement with the test. Because so much of the test was unfamiliar to the students they needed constant re-assurance to keep trying to answer all questions.

5. Recording student experiences: During the unit, the two observers kept a continuous record of the behaviours, sources of information, and contexts for each selected student. Each observer was responsible for two students, alternating observations by observing one for 15 seconds and then the other for 15 seconds. Six miniature video cameras were positioned in the ceiling of the classrooms, with four monitoring the behaviour of each of the selected students and two (with wide-angle lens) monitoring the spaces in which the teacher conducted whole-class discussions. All the students in the class wore miniature broadcast microphones. Although all these microphones looked identical only those worn by the selected students were live and made continuous recordings of everything the students said and heard during the units. Records were also made each day of everything the selected students read, wrote, and saw by photographing or photocopying wall displays, pictures and text in books, and the students' own project books. The students were also asked to fill in each day a record of anything, including homework, they did outside of class time that was related to the unit in any way.

6. Immediate post-tests and interviews: The outcome test was administered a second time about two weeks after the unit, and the selected students were interviewed (by the author) about their understanding of test-item content and their memory for relevant classroom experiences. During these interviews an unanswered copy of the test was open in front of the student. For each item in the test, the student was asked to describe the correct answer, to recall how she/he had learned that answer, and to recall any experiences or activities that were relevant to the answer.

7. Video-cued interviews: An additional set of interviews was interspersed with the post-test interviews. In these interviews, the students were shown video-clips of themselves engaged in tasks in the classroom and asked to talk about their experiences during those tasks. The format of these interviews is described in more detail below.

The video-cued interviews

The purpose of the video-cued interviews was to get the students to talk about how they experienced specific incidents during the units. The video-clips used with each student were selected from the video-recordings made with the camera that focused on that student and other members of her/his group, and the camera that recorded teacher-led whole-class discussions or demonstrations.

Segments of the video recordings were identified that recorded the student's behaviour at moments that our model of the learning process suggested were critical to the learning of specific concepts or principles. These were moments when, for example, the student asked the teacher for information, discussed information or an experience with peers, observed something significant (e.g., the image in a concave lens) or appeared to be sitting and planning what to do next. Moments when students expressed surprise, dismay, or were saying something apparently significant to themselves, were also included. Not all such moments could be included, so a sample of those were selected where the event or activity was clearly visible and the talk clearly audible. The number of video-clips used with each student is reported in Table 2. The differences in the number of video-clips used reflects the amount of good quality video-recording that was available for each student.

Insert Table 2 about here

There were difficulties in completing the full timetable of interviews. On occasions it proved impossible to find a time when a suitable room was available and the student would not be disadvantaged by missing classroom work. Interviews with two students in Study W9 were abandoned because a suitable room at a suitable time could not be arranged. Some parts of some interviews, and the entire interview with one student in Study W7 could not be transcribed because of technical difficulties with the recording equipment.

The interview were planned to be relatively open-ended, beginning with more general questions and ending, where appropriate, with more specific and probing questions. The students were shown a number of video-clips (mostly of the whole class) at the beginning of the interview to help them get used to the experience of watching their class and themselves on tape. This was accompanied by informal discussion of who could be seen on the video-tape, what everyone was doing, and so on. The following excerpt from the beginning of the interview with Jordon (Study C10) illustrates this process. The video-clip shows the class sitting on the carpeted floor around the teacher.

I There you are. Everybody's getting down on the mat. You can see people. Can't see you yet. Don't know where you might be sitting.

J Oh, there I am.

I Oh, there you are coming over now. No wonder I couldn't see you. That's you. And Douglas. Is that Douglas?

J Yeah.

I Seth is it?

J Yeah.

I Can't see very well there. Warren, Eleanor, Morgan ..

J That's Darren.

I Darren. Yes. It is Darren. He's talking to the teacher. There's Warren. Margery. That must be ..

J That's Malcolm. Then behind him's Isaiah and next to Isaiah is Troy.

I Troy. Right. She's [the teacher] talking about that, where you had a glass and put a pencil in it. Do you remember away back then?

J Yep.

When the first of the video-clips to be used in the interview was shown, the student was asked to talk about what was going on for her (him) at the time. The opening questions included "What was going on for you here?", "What's this like for you?" "What's happening here?". Subsequent questions related to the student's responses, and encouraged the student to talk more about her/his experience and/or thinking.

If the student's initial responses to a video-clip indicated that the student did not recall the incident being watched, or had a very vague recollection of what was going on, then there was no further questioning, and the next video-clip shown. If the student did respond with details of what was happening, or of what the student was thinking or experiencing, then further questions were asked. These questions were intended to make

it clear that the interviewer wanted the student to describe anything and everything being experienced, felt, or thought about, during the incident being viewed, without focusing or structuring the student's responses. The following excerpt from the interview with Sylvia (Study C10) illustrates this procedure. In the video-clip *Sylvia was looking through a concave lens* and said something to herself.

I There you go. You said "Ooh, that's tipped over, that jar". Tell me about that.

S Yeah. It looked like it. 'Cause when I looked through it, I was holding it about there and then the glass was about there, it looked like it was tipped over.

I That's interesting.

S It might have been just the way I was looking through it, the way I was holding it.

I The way you were holding it. It looked as though it was tipped over?

S Yeah.

I That was a surprise to you?

S Yeah. Cause it's usually big or blurry. 'Cause it's convex.

I Yes. That's interesting. I wonder what you, why you thought that would happen?

S I don't know.

I Interesting. Yeah, go on.

S It um, it might be the angle that I was looking at it from. And how close it was or far away ... etc.

Because of the practical problems involved in finding appropriate interviewing places in the school, and timetabling the interviews while the observing and recording in the other classroom was still going on, the length of time between an incident occurring in class and the student viewing that incident on a video monitor, varied considerably. In some cases (e.g., with the students in the last study, C10) it was possible to keep this time interval short (only 1-2 days). The average time delay was about 20 days. The actual time delay for each student is listed in Table 2.

Analysing the interview data

Transcripts of the students' interview responses to the video-clips were sorted according the major focus of what they said about their experiences during the recorded incidents. Responses were not classified if

they were nothing more than a description of what the student could see and/or hear on the video-clip. To be included in the analysis, they had to refer to something that was recalled from the occasion in the video-clip, but was not actually visible or audible.

Four general types of responses were identified. The first were responses in which the student described what was happening but without describing or referring to any thinking process or to an outcome of any thinking that occurred at the time. The response was confined to what happened, what was said or heard, seen or experienced. The second type of response was one in which there was reference to (or description of) a thinking process taking place at the time or to the outcome of a thinking process. The third type of response was one in which the student described her/his feelings or reactions to an event or behaviour or object. This included expressions of interest, excitement, puzzlement, confusion. The fourth type of response was one in which the student engaged in further relevant thinking during the interview itself. These were occasions when watching the video-clip restarted the thinking that had occurred at the time. While talking about the incident, the student reached a conclusion or made a discovery that had not occurred at the time. Examples of each of these types of interview responses will help to illustrate how the students responded to the video-clips, and further illustrate how the interviews were conducted.

1. Student recalls activities, behaviours, experiences, perceptions

Some of the responses classified in this category were simple descriptions of what happened. In the following example, Julie (Study C8) can be seen drawing a ball and rubbing it out.

I Now, in a little bit, Margery comes over I think here.

J And she probably grabs a pen out of my pencil case.

I Does she do that does she?

J Yeah. Because she has colour pencils but like, they don't work very well and they're all colours like yukky colours. So she always comes over and gets . ... Yeah. Oh, I was doing [drawing] a ball. I was doing two, a ball there, and I was doing one round, but it kept on being too big and (inaudible) so I ended up just doing one ball.

I One ball?

J Yeah.

Other responses described what the student or others had said or heard, seen, written, or read. For example, in the video-clip for the following

excerpt, Jordon (Study C10) can be seen polishing a spoon and looking at his reflection in the spoon. This excerpt comes from the middle of Jordon's response.

I ... What do you look like in the spoon?

A Well, on one side it looked upside down and the other looked, um, a lot bigger. Huger.

I Huger?

A Yeah. Like if you put your finger up you could see like your finger looked really big and huge.

I Oh, you mean it looked really .. ?

A Yeah. Like if you put it on the spoon like that. It would look ..

I On the back or the inside?

A Like go out on an angle so it looked a lot bigger.

I Yeah. Is that on the inside bit or the ..?

A Inside I think. And the outside made you look upside down.

Responses that included not only the activity but the outcome or result of the activity were also included in this category when there was no description of any thinking process that led to the outcome or result.

2. Student recalls what she/he was thinking about, or the outcomes of thinking

Responses classified in this category included a description of the thinking process or of the outcomes or results of thinking that apparently occurred at the time of the incident in the video-clip. In the following example, Jordon (Study C10) could be seen in the video-clip looking through a small lens that he had just taken out of a case containing several lens.

J Margery's got one and I've got one. (inaudible) actually convex. They were muddled up in the cases.

I Were they?

J I worked out that, that concave was the one that was curved in as a cave.

I As a cave. What did it look like looking through a concave one?

J Everything looked small.

I Did it? Did you know that before?

J Um, I hadn't even heard of the word 'concave'.

His response described the results of what he "worked out" at the time. It included a description of what he saw and his judgement that this was

entirely new knowledge for him. In the following example, the student's response follows a probing question about what she was thinking. In the video-clip, Sylvia (Study C10) could be seen looking through a sheet of red cellophane. In the interview she had just described what she had seen through the cellophane.

I If I were to ask you what you were thinking when you were doing that, I wonder what it would be?

S Well, when I looked through that, it looked like everything was clean and it was, all the school uniforms were purple and parts of Isaiah's jersey, they come out red. They come out a funny colour. 'Cause his top, um, was blue and it had patches of white and stuff on it. It came a different colour.

I So it made the world look different. Really different.

S Yeah.

I Why do you think it's like that?

S Well, it can mix like, white and red make pink, and red and blue make purple.

Although Sylvia's response was a further elaboration of her description of what she saw, it was classified as a report of her thinking because it was her response to the interviewer's specific "thinking" question.

The reasons that students gave for their actions or decisions were also classified in this category. The presumption is that recalling the reasons or considerations that were significant at the time reflects the thinking that must have been going on at the time. In the next example, Eleanor (Study C10) could be seen talking to the others in her group and turning back through her report folder.

I ... What were you looking back to? What was going on here?

E I think we had, oh um, I was looking back to use some information that I'd learnt before.

I Do you remember what the information was?

E Um, it was to do with the convex and the concave mirrors.

I Right. OK. So you must have remembered that you'd written it before.

E Yeah.

I Wonder what it was.

E I think it, it was when we did the stuff to do with the little mirrors, um, the concave and convex. Cause I think I looked back to find out which one. The concave looks, makes it look smaller.

The other responses coded in this category included descriptions of the purposes or intentions that lay behind activities, confusions and misunderstandings that were reflected in student behaviors, and references to previous or other knowledge that was being considered.

3. Student recalls what she/he was feeling at the time of the video-clip.

This category includes descriptions of feelings such as feeling frustrated, bored, interested, puzzled, and descriptions of feelings about self, and self-evaluations. In the following example, Kirk (Study C8) described his feelings when the teacher was giving instructions to the class about how to carry out a task.

I Can you hear the teacher? What's it like for you when the teacher's reading instructions?
K Oh, get it over with.
I Want to get it over with?
K Yeah.
I Is it boring?
K Yeah.
I Does it make you feel worried?
K Nah.
I Just want to get it over with.
K Yeah.
I So you can get on with ..
K Yeah. Get on with doing it.
I Doing it?
K Mmm.

Students also described their feelings about other students and about class activities and the objects they encountered during the activities. In the following example, Seth talked about an occasion when he showed some of his work to Sylvia and she ignored him. He politely excused her behaviour.

S Yeah. I was doing (inaudible).
I What are you feeling there?
S Oh, a bit frustrated.
I Frustrated?
S Yeah. I was trying to get her attention but she kept on working (makes frustrated noise).
I Yes. Does she not pay much attention to you?

S Oh, no .. it was, she was really doing something and she probably didn't want to forget it.

4. Thinking during the interview

This fourth category included those occasions when it was clear that the students restarted the thinking that they were engaged in at the time shown on the video-clip. The kinds of responses classified in this category are discussed in more detail in the next section of this paper.

Details of the specific types of responses that were included within each category have been listed in the Appendix.

The frequency of the different types of student responses

The number of interview responses that were classified for each of the students has been reported in Table 2. The number of responses is greater than the number of video-clips because there were occasions when the student responded differently to different parts or aspects of the video-clip. For example, a student might provide a description of her/his perceptions during the activity seen on the video-clip, and then go on to describe her/his feelings about a different aspect of the activity. These two types of responses would be classified as separate responses.

Table 3 reports the results of classifying all the students responses to the video-clips. Included in this table are two categories for occasions when the student could not recall what was happening in a video-clip (1.5 Cannot recall activity, experience) or could not recall that she/he was thinking at the time when asked directly by the interviewer (2.10 Failure to recall thinking).

Insert Table 3 about here

The "activities and perceptions" category included about 45% of the students' responses; the "thinking and outcomes of thinking" category included about 40% of the students' responses. Most of the rest of the students' responses described their feelings and reactions to objects and activities.

As a general summary, it seems that the students were able to recall either their thinking processes or the outcomes of their thinking for about a third (37%) of the video-clips they were shown.

Forgetting classroom experiences

A further analysis was carried out to determine how the students' responses to the video-clips were affected by the time delay between the occasion recorded on the video and the time of the interview. It seemed likely that the nature of what the students could recall would be strongly affected by the length of time that had elapsed between the original experience and the time the student was asked to recall the experience. Other researchers have argued that thinking processes can only be recalled immediately after an experience. Delay results in complete loss of recall. Our own research has shown that there are substantial and predictable effects of memory loss when students are asked to recall how they learned from their classroom experiences (Nuthall & Alton-Lee, 1995; Nuthall, in press, a).

In order to create a clear picture of possible changes due to the time lapse between experience and interview, the students interview responses were re-classified into categories that seemed more likely to reveal significant changes in the content and quality of their recall. This was done by distinguishing between responses that reported thinking processes, and responses that reported the outcomes of thinking. The latter seemed more likely to be recalled later because of their more abstract and general nature. A distinction was also made between responses that reported activities and behaviours, and responses that reported the details of perceptions and experiences. It was thought that these two types of responses might be differently affected by the forgetting process. The categories for failure to recall activities and behaviours and failure to recall thinking processes were retained as specific categories.

The results of analysing the students' responses by length of delay between the original experience and the video-cued interview are reported in Table 4.

Insert Table 4 about here

It is clear from the results in this table that the students remembered their experiences in the science units differently from their experiences in the social studies units. They were more likely to recall thinking processes and their perceptions and experiences in the science units than they were in the social studies units. They were more likely to recall activities and behaviours without reference to thinking processes or the products of thought in the social studies units. In addition they were more likely not to

be able to recall anything about the occasion seen in a video-clip in the social studies units than they were in the science units. Taken together, this adds up to a shift away from recalling thinking processes and away from recalling the details of activities and behaviours in the social studies units.

Since most of the interviews for the social studies units were carried out after a longer time delay than the interviews for the science units, it is tempting to conclude that memory for thinking processes does disappear with time. However, for those interviews that were carried out with the same time delay for both the science and the social studies units (the 15-17 and the 20-24 day time delays), the contrast is still clearly evident.

Two conclusions seem warranted from this evidence. What students can recall about their classroom experiences is strongly affected by the nature of the activities they have been engaged in. They are more likely to recall their thinking processes and the details of their activities and their perceptions from the kinds of activities that occur in typical science units than they are from the kinds of activities that occur in social studies units.

However, this conclusion needs to be treated with considerable caution. What is not evident in Table 4, but became very clear during the interviews, was that there were substantial differences between individual students in their ability to recall thinking processes and the details of experiences and perceptions. Because the same students were not interviewed in both the science and the social studies units, there is no way, with this data, of entirely disentangling the effects of curriculum and/or task design from the effects of individual differences. Further detailed analysis may help suggest whether individual differences can entirely account for the apparent differences between the science units and the social studies units.

The second conclusion that seems warranted by this data is that the time delay is not as significant as predicted. Careful examination of the data within the science units, and within the social studies units, shows very little systematic change that could be attributed to the passage of time. For example, recall of thinking processes within the science units seems to be highest with an 8-10 day delay and lowest with a 1-4 day delay. Since the same students (in study C10) were involved in these interviews, this cannot be accounted for by individual differences. Within the social studies units, recall of thinking processes seems more likely the longer the time delay.

Accounting for this unexpected finding raises a number of interesting questions. One potential explanation is the nature of the interview process. The interviews were relatively open-ended and every attempt was made

not to structure the students' responses. This meant that the interviews were sensitive to the content of the video-clips and the possibility that the selection of the video-clips shaped the nature of the students' interview responses. Presumably, however, the selection of the video-clips reflected the differences in the activities that occurred in the two curriculum areas. A lot of the activities in the science units involved materials (e.g., colored cellophane, magnifying glasses, prisms) and the manipulation of materials. A lot of the activities in the social studies units involved reading books and looking at pictures. Although the students found the social studies units more interesting, the science activities provided video-clips that contained more action and varied materials.

Another possible explanation is that the video-clips were a very effective method of cueing memory for these students. This presumes that memory for classroom experiences is stable, and although students may not be able to recall their experiences under normal conditions, when an experience is reinstated by a video-recording, that memory becomes available. The implications of this possible explanation need further examination.

How do students recall their thinking processes?

In this section, the students' interview responses are examined for what they say about the ways in which students engage with classroom tasks. How do they engage with the tasks and how does their engagement structure their thinking?

Initial analysis of the ways students talk about their experiences of classroom tasks indicates that their primary focus is on the practical aspects of getting tasks completed. Instead of talking about the intellectual demands of the tasks, their recollections relate primarily to obtaining and managing the materials and resources required for carrying out the activities or locating and writing answers to questions. When Austin was asked what he was thinking as he read the instructions for a task, he replied

> A Yeah. We had to write down what we did. We were meant to write what we did, what happened and what we discovered. And like we had to stick that in our books just to say what we did it. 'Cause, to show that we did that.

The result of this focus is that students tend to look for the shortest and most efficient way to complete the task requirements regardless of the intended purposes of the task. When Kent was asked about the way he

completed a task in which he had to describe the lives of women in ancient Egypt, he indicated that he looked for any answer that completed the task as quickly as possible.

I What did you decide do you think? [how were women treated]

K Bad.

I Bad. Why was that?

K I don't know. Just wanted something to write.

I Sorry?

K I just wanted something to write then.

I You just wanted something to write then so you just made a decision as the best thing cause you wanted to get on with it did you?

K Yeah, cause that was the last thing I had to do.

When students recalled the way they decided what to do, considerations of ease and efficiency were frequently mentioned. For example, in Study W7, the students were asked to draw something significant about life in ancient Egypt that was to become part of a class mural. Amity spent time looking through books to find a suitable picture. When she was asked what she was thinking as she looked through a book, she explained that she was looking for something that was easy to draw.

I And you're looking for something. Ah, you've found it in the other book. You're making a decision about something. I wonder.

A I think it was that um, that mask on Tutankhamen's thing. I was going to draw that but I found it was too complicated.

Sometimes the reason for this focus on finding the easiest path to completion of the task came from the fact that the students already had the knowledge required to complete the task. They did not feel they were learning anything new and consequently did not feel that the task warranted more than a superficial involvement. In Study W9, the students were asked to study how a picture was reflected in the side of a shiny curved metal bowl. They were asked to draw a picture and then make another picture of how it was reflected in the side of the bowl. Austin, like many of the other students found this a confusing task to complete. When he was shown a video-clip of himself studying the reflection in the bowl, he said he was not concerned that he was not able to complete the task.

I Right. What does it feel like when you try something like that and ... it isn't working?

A Doesn't worry me.

I You don't mind? Did you know that before that?

A Well, I knew that if you like had a mirror and you got a reflection it would look all big and tall. So yeah (I did?) know that.

In general, students seemed unaware of the intended academic purposes of the tasks that they were asked to do. When Austin was engaged in a similar task involving looking at, and drawing the reflection of his face in the two sides of a shiny spoon, he was asked what he thought the purpose of this task might have been.

I Why do you think the teacher wanted you to do that? Why do you think you were studying spoons? What was her idea?

A 'Cause like it was the only thing that was curved and you see in it. 'Cause like you couldn't really curve the mirrors.

I Oh I see. Right. So the spoon was a good way of doing that. But why would she want you to look in a curved mirror anyway? What do you think she wanted you to learn?

A What we looked like in a curved mirror.

I Why would she want you to learn that do you think? What do you think's the purpose of all this?

A To learn things.

I To learn things. Just to learn something more and different?

A Mmm.

Austin's response to this question suggests that his notion of purpose and the interviewer's notion of purpose were different. His notion was primarily practical. Spoons were used because the teacher could not get curved mirrors. The purpose of curved mirrors was to see what you would look like in a curved mirror. Only after persisting with the question did the interviewer elicit the vague response "to learn things". It is as though there really is not a purpose to the classroom tasks except getting them completed. When Jordan (Study C10) was asked about the purpose of the task he was engaged in, he gave the impression that it was an irrelevant question

I When you do those things the teacher asks you to do and you're just starting them, do you know what they're for a lot of the time, or sometimes, or do you just start off doing them anyway and see what happens?

J Yep.

I Yeah. Do you wonder what for?

J No. Cause the teacher's usually told you.

I Told you. Yes.

One of the consequences of the students' concern for getting tasks completed was that they saw the teacher's involvement with their activities as a intrusion. When the teacher asked them to stop and listen to further instructions, or joined their group to assist or re-organise their activity, they reported feeling annoyed and frustrated. When Alice (Study W7) was asked what she was thinking as she listened to the teacher giving instructions, she reported mild frustration.

I What do you think about when the teacher's giving instructions?

A Oh, I'm usually thinking um, oh, yeah OK, I'll do that.

I Are you? Yeah.

A Yeah. But it's like I've, I want to get finished what I'm doing now and then go on to it.

I So you feel as though you're being interrupted?

A Yeah.

When Kent (also in Study W7) was asked what he was thinking when the teacher came to his group to help them with their task, he was less polite.

I What's it like when Mrs W is helping you? What does it feel like?

K Boring.

I Is it?

K Annoying, she's ... She's always telling you what to do and stuff about work.

These examples seem to indicate quite clearly that the students' primary concern was with the physical aspects of completing tasks. They described thinking about the pens and paper, the books, the scissors, the materials and other resources they needed to finish the tasks they were set. In many of their descriptions of their thoughts and feelings during the classroom tasks there was no mention of any academic or curriculum purposes. From these descriptions, life in the classroom seemed to have little, if any, intellectual challenge and the students had little, if any, awareness of the teacher's educational purposes.

However, such an analysis presumes that there is a clear dichotomy between the cognitive and the physical aspects of tasks. It presumes that the students were able to distinguish clearly between thinking and doing and that when asked to talk about how they experienced classroom tasks, they would identify these two aspects separately. If the distinction between thinking and doing, that is common in much of the cognitive literature on learning in classrooms, is discarded and a more sociocultural perspective

taken, then the data reveals a very interesting integration of thinking and doing within the students' reported experiences.

Often when the students were asked specifically about their thinking, they reported their own or other's activities. One of the tasks in Study W9 was to compare the magnification effect of looking through a small drop of water with looking through a large drop of water. Many of the students found this a difficult task, and the teacher often helped a group to carry it out. In this example, the teacher was working with Sonya's group.

I What do you think you're thinking now while you're watching?

S Which one magnifies better.

I Which one magnifies better?

S Yeah.

I Yes. Do you think you thought you got it wrong before?

S I wasn't too sure.

I You weren't too sure?

S No. Cause Alice was saying that it magnified little and I said it magnified big and Mrs W said "We'll just see about that".

Sonya described her thinking in terms of what she and Alice and the teacher had said. Similarly, when Sylvia (in Study C10) was asked what she was thinking, she described what she was seeing. The video-clip that she was looking at showed her looking through a sheet of red cellophane at various objects around the room.

I If I were to ask you what you were thinking when you were doing that, I wonder what it would be.

S Well, when I looked through that, it looked like everything was clean and it was, all the school uniforms were purple and parts of Isaiah's jersey, they come out red. They come out a funny colour. Cause his top, um, was blue and it had patches of white and stuff on it. It came a different colour.

I So it made the world look different. Really different.

S Yeah.

I Why do you think it's like that? Why do you think the red cellophane does that?

S Well, it can mix like, white and red make pink, and red and blue make purple.

It is interesting to note that sometimes the students' responses were ambiguous because the terms that are used for thinking processes in English make use of analogies between doing and thinking. In the following

example, Dean (Study C8) was asked what he was thinking as he read through a sheet of instructions.

I Yeah. I wonder what you're thinking here?

D I was looking for somethink.

I Looking for something in the instructions?

D Yeah.

I Yeah.

D Which we did at (inaudible).

Dean was in fact 'looking at' the sheet of instructions. The meaning shift from 'looking at' to 'looking for' is subtle and ambiguous in the English language.

This apparent translation of 'thinking' into 'saying', 'seeing', and 'doing' may well reflect a lack of distinction in the minds of the students between thinking, perceiving, and doing. It is, however, more complex than this. Tasks were often designed to involve the students in a problem solving activity. When the tasks were group tasks in which the students had to interact with each other and co-ordinate their actions, the process of problem-solving became a communal process in which thinking was a shared interactive process not an internal individual process. Consequently when students talked about the process of solving the problems set by a task, of making decisions and reaching conclusions, they described discussions and the resolution of differences between each other. For example, when Amity (Study C8) was asked what she was thinking while she traced a picture of a pyramid onto a piece of paper, she described a discussion among the members of her group about drawing pyramids.

A Um, I was going to trace it. Julie said "Just do a triangle".

I Oh right. That'd make it easier for you?

A Oh, Sylvia said "You just draw a little, like oblong cup type thing to make one, a smaller one each time".

I Oh, I see. You mean like a little brick, and then a smaller and then a smaller and a smaller?

A Yeah. Like um, that and that. (demonstrates)

I Yes. And then a smaller one on top.

A Yeah. Until you get to the very top.

In a video-clip from study A9, Austin was writing answers to questions about light and rainbows on a worksheet and talking quietly to his

neighbours Mary and Derek. When he was asked about what he was thinking, he described a disagreement he was having with Derek.

A Oh, 'cause Derek just said that rainbows happen just when the sun comes out after rain. And I said we have to do it like scientifically, like little raindrops bend the light to make colours. Just like a simple thing like that.

I Right. That's a proper scientific description of it?

A Yeah.

I Yes. Why did you, why wasn't his one scientific? When he said it just comes out with the rain, like that.

A Well, he just said like it came out, rainbows happen when the sun comes out after rain. And it wasn't like just scientific.

I You don't think that's scientific?

A No.

I So what would make a scientific sort of one?

A Like when this, rainbows happen when, when, after rain when the sun bends the light of the raindrops.

I Right. So that's right. Yes.

A The raindrops bend the light of the sun.

In both these examples, the thinking process is equated with the discussions that took place and consist of recollections of what each person said. Thinking and saying are treated as the same process where the content of the thinking (the alternative points of view) have become the focus of the description rather than the process.

This does not mean, however, that the students did not make any distinction between thinking and doing, saying, or perceiving. They also indicated an awareness that a distinction could be made. For example, when Amity (Study C8) was asked about an occasion when she was talking to the others in her group, she distinguished between thinking and talking.

I What were you talking about here?

A Oh, um, we were arguing over um, if pyramids had a door or not.

I OK. What were you thinking there, do you think?

A Um, I don't know.

I Did you .. Did you decide they did or they didn't in the end?

A Um, well I went and asked Mrs C and she said that um, they do have an entrance but then they close it up.

Quite what Amity was referring to when she said "I don't know" is not clear. She made the distinction between her general description of the

discussion ("we were arguing over ..."), her recall of the solution to the argument ("I went and asked Mrs C. ...") and her response to the interviewer's specific question ("What were you thinking there ..."). It may be that she could not recall what they were talking about on the precise occasion she was seeing in the video-clip.

The other situation in which problem-solving is equated with behaviour is when the process is one of trial and error. There were occasions when students described arriving at solutions by just trying something out. In one of the video-clips that Seth (C10) looked at he was writing the word 'BOO' on a piece of card and said the word to himself. It was part of a task in which the students were required to write something by looking in a mirror (mirror-writing). Seth had discovered that this was easy if the letters were symmetrical.

I Did you really plan it that way?

S No. I didn't plan it that way. I just writ the word.

I Just the way it came. Yeah.

S Yeah. (inaudible) would be symmetrical. ... Depends how you do it. ... Ah, the B and the O and the O come out exactly the same.

I Oh, that's because it's symmetrical?

S Yeah.

I Oh right. So you discovered that really?

S Yeah.

I Worked that out for yourself?

S Yeah.

Similarly, Amity (Study C8) described how she managed to draw a pyramid after a series of 'helpful' suggestions from other members of her group.

I So how did you start drawing a triangle? How did you decide to do it?

A Um, Sylvia tried.

I Sylvia tried doing the ..?

A Oh, I tried doing that like, start at the top and then you go like, um, that .. (demonstrates?) But it didn't work out.

I You're trying to go down the steps like that.

A Yeah.

I But it didn't work out.

A No. It looked weird.

In both these examples, the process of carrying out the task involved trying out alternative solutions. The students' descriptions of how they reached

the solutions (e.g. "How did you decide to do it?") were descriptions of what they did rather than of any different or distinguishable thinking process.

One of the consequences of not distinguishing between thinking and activity is that recollections of the problem-solving process contain much of the detail of what was said and done during the process instead of just recalling the conclusion or the solution to the problem. The effect is that the problem-solving process seems to have been stopped off at the practical level. While students may be surprised, confused, or puzzled by the solution that they have worked out, resolving the confusion or surprise is irrelevant to completing the task and remains unresolved. In the following example, Austin (Study W9) was engaged in using a torch to create a shadow of an object on a wall. The purpose of the task was to find out if the edges of the shadow were sharper when the object was closer to the torch.

I ... Far away from the torch it's sharper?

A Yeah.

I So that's something you discovered then?

A Yep.

I Yeah. Why do you think it's sharper when it's further away from the torch?

A Well, because it's um .....

I Mmm?

A Dunno.

For Austin it was sufficient that he had found the answer. He appeared to have no further interest in what he had discovered. In the following example, Sylvia (Study C10) is in the process of discovering something about the way a lens distorts an image. The video-clip showed her looking through a lens and saying to herself, "Ooh, that's tipped over, that jar".

I ... You said "Ooh, that's tipped over, that jar". Tell me about that.

S Yeah. It looked like it. 'Cause when I looked through it, I was holding it about there and then the glass was about there, it looked like it was tipped over. ... It might have been just the way I was looking through it, the way I was holding it.

I That was a surprise to you?

S Yeah. Cause it's usually big or blurry. 'Cause it's [the lens is] convex.

I Yes. I wonder what you, why you thought that would happen.

S I don't know.

I Did it, did you sort of think to yourself, why is it like that, at all? ...

S It um, it might be the angle that I was looking at it from. And how close it was or far away.

I Right. Why does a magnifying glass do that? What's happening to the light or to what you're seeing?

S Um, well it gets bigger sometimes and sometimes blurrier.

I What makes it do that do you think?

S Um, the kind of glass it is. Like, the fatter thing.

I Yes. Had you ever thought about that?

S No.

During this interview, the interviewer's questions started Sylvia thinking about how the lens might have produced the upside-down image and she gets close to identifying the shape of the lens ("the fatter thing") as part of the answer. However, as she made clear twice in the interview, she had not thought about it before ("Had you ever thought about that?" "No.").

The implication of responses like Sylvia's is that students retain a memory for their activities and the outcomes of their activities without necessarily thinking through the implications or the reasons for their experiences. The raw evidence of their experiences remains suspended in memory unprocessed but available for use in answering questions such as the questions posed by the interviewer. In addition, there is evidence that students store several layers of an experience including what they used to think or understand before the experience. Sylvia, for example, recalled what she believed before the discovery discussed in the previous example.

I Right. Did you have any idea what it would look like before you saw it?

S Um, well, the convex I knew what it looked like but the concave I didn't know.

I You didn't know?

S No.

I So that's something new for you?

S Yep.

This memory for previous beliefs also contains information about where the new ideas or thoughts came from. In Study W7, the students were asked to write a letter of application for a job as though they were living in ancient Egypt. In a video-clip of herself writing this letter, Alice can be seen writing something at the top of the letter.

I What are you thinking?

A Oh, I was thinking "Oh, what could that [date] be?"

I Right. And how did you work it out?

A Because it was BC and so I just put like 2500 BC.

I Why did you think that?

A Oh, because of the time thingy on the wall. Timeline on the wall. It had when the pyramids were built and um, it had ..

I So you must be remembering that there because you're not looking at the time line are you?

A No.

What Alice recalled was the source of the date she wrote at the top of the letter. Although there was a timeline on the wall across the back of the classroom, Alice did not look at it during this episode. So her recollection of the date that she wrote included her recollection of how she had worked out an appropriate date.

There were several occasions when it seemed that the interview itself triggered further processing of the information stored in memory. During the incident (in Study W9) when the teacher was working with Sonya's group experimenting with the magnifying effects of large and small drops of water, Sonya recalled that she did not know why the smaller drip magnified more. ("I'm still not sure why it magnifies better than the big one"). Then, as she watched more of the video-clip, the answer occurred to her.

S Oh, cause it was rounder!

I That's right. It, a big one is flat and a little one is .....

S Round.

I Rounder. So it bends the light more.

S So that's why it magnifies better!

I That's why it magnifies better.

S Oh!

It seemed from some of these incidents that the processing of the classroom experiences had not been completed and was still, in some sense, in progress. When Eleanor was interviewed about her thinking while she was looking through different shaped lens, the time-lag between the original experience and the interview was only three days. She seemed to be still wondering why the concave lens made things look smaller.

I Did you wonder why they were smaller?

E I don't know why it's smaller. Probably because of the shape.

I Yes. Did you imagine why? Any thoughts about it?

E Well, maybe how, seeing it goes like that when you're looking through it, um, it maybe it looks smaller because it turns round and ..

I Yeah. Keep going. Something to do, you think, with it being round like that.

E Yeah. ... I think it's cause um, the light goes, it reflects into the middle and it sort of makes the words look smaller.

I Yes, go on.

E Because it, because when it curved, the light would go through it and hit, and go ... (demonstrates with hands)

I Go inwards?

E Yeah. And when you look through it, it makes it look smaller.

I That's interesting. Yeah, that makes sense doesn't it?

E And with the big, and when it's convex, the light goes out that way so it's so it makes it ..

I So it makes it look bigger?

E Mmm.

I Now, did you just work that out then or had you thought about that before?

E Well, I was thinking of it but I didn't know how to put it.

I Oh, right. Do you think you were thinking about it then [at the time of the video-clip]?

E I don't think I was thinking about it then.

I Not then. No. Just when I've asked you, do you think?

E Yeah.

If you take a continuous view of the relationship between the original classroom activity and the interview as another activity, then the process of thinking through the classroom activity is continued in the interview. What changed was that the classroom activity required that the student to do no more than look through the lens and record the nature of the image that she could see. The interview required a recollection of that experience and in asking about the student's thinking at the time, implicitly required a further interpretation of the experience. The result, as the excerpt above shows, was that Eleanor worked out a reason why the lens produced a smaller image during the course of the interview. The transcript of the interview is a record of Eleanor's thinking process as it occurred through her talking with the interviewer.

Thinking as an internal process

The account of how students talked about their thinking processes must also include those occasions when the thinking occurred in the absence of external activity. Some of the video-clips were chosen because they appeared to be occasions when the students paused to think. They might have stopped an individual activity and be staring out of the

window, sitting listening to the teacher without contributing to the discussion, or sitting watching other members of their group carrying out a task.

In Study W9, there was a task in which the students were required to write a secret message (using colours invisible through coloured cellophane) to someone else in their group. When Austin was working on this, he paused and whispered to himself, "I'm writing to Derek".

I What do you think you were thinking then?

A What to do. Cause I think .. I was just thinking what to do.

I Thinking what to do?

A Yeah. Cause I think I was um, like, Derek and Mary were there and like, I had to write to one of them in the message. I drew it to Derek I think. Just trying to figure which one I drew it to.

I Figure out which one you had to write to?

A Yeah.

It appeared that Austin paused in his activity because he needed to make a decision before he could proceed. Deciding which student he wrote to determined what he wrote in his secret message. There were other occasions when the need for a specific decision was not apparent. Sonya (Study W9) was sitting watching Alice writing her report of the results of their experiment with reflections in spoons.

S (laughs) Yeah. I was looking at Alice's.

I Yes. Do you stop and think sometimes?

S Mmm. Yep.

I Think you might have been thinking there?

S Mmm.

In this example Sonya (prompted by the interviewer) recalled the occasion as one in which she had stopped to think. She was not able, however, to recall exactly what she was thinking about. Some students responded in the same way to video-clips of them sitting listening to the teacher talking to the whole class. In the next example, Jerry (Study W7) was sitting listening to the teacher giving the class instructions about homework. The teacher had suggested a set of alternative homework activities.

I ... What's Jerry thinking about there? ... Do you remember?

J No.

I Not really. What do you think you might be thinking about? Feeling?

J Oh, what I'm going to do. What things I'm gonna do.

I Which one you're going to do?

J I did mine in the book.

There were also occasions when the student indicated that the thinking was not related to the ongoing activity. In the following example, Jordon (Study C10) was sitting listening to the teacher talking to the whole class. The teacher had placed a pencil upright in a glass of water and asked the class, "If you look at it from the side, what happens to the pencil'?

I What do you think you're thinking when you're sitting there?

J I don't know.

I What would you be thinking? Can you remember at all? When she's talking, got the glass and pencil and things.

J No.

I Were you thinking about something else?

J Think I knew it all so I wasn't really interested.

I Right. OK. ...

J I might, I think I was thinking about the, what the next experiment was going to be.

Given permission by the interviewer, Jordon indicated that his boredom led him to thinking about what the teacher might do next.

Summary and conclusions

The use of relatively open-ended interviewing procedures with video-clips in this study was relatively successful. Even though the time lapse between some interviews and the original experiences was as long as 35 days, it produced surprisingly detailed recollections of a wide range of different types of experiences.

About 38% of the students' responses described their experiences without reference to any thinking process or to any cognitive outcomes. They recalled what they had heard, seen, done, perceived, produced. In a further 36% of their responses, they recalled something about their thinking during the incident or activity recorded on videotape. In these responses they recalled their intentions, their decisions, their state of confusion or surprise. They recalled the sources of their ideas, the reasons and ways they reached conclusions, the connections between new ideas and old beliefs.

A further 14% of their responses related to their feelings about their activities and themselves. They described what they felt about the teacher

and their peers, their own likes and dislikes, their reactions to events and other students.

Although a significant number of the students' responses made reference to thinking processes or to the outcomes of thinking processes, most of the content of these responses was closely related to their behaviours and perceptions. The overall impression of the content of their responses was that the students' minds were focused primarily on getting things done, on managing and completing the tasks they were required to carry out.

Previous research (e.g., Bloom, 1953) suggested that recall of thinking processes would be strongly affected by time. However, in this study, even though the time-lapse between the original activity and some of the interviews was as long as 35 days, there were only about 6% of the recorded activities that the students could not recall at all. An analysis of the relationship between the nature of the student responses and the time interval between recording and interview, showed no systematic differences. Instead there appeared to a substantial difference related to the curriculum area, or the types of tasks. Students were more likely to recall thinking processes during tasks in the science units than they were in the tasks in the social studies units. They were also much more likely to recall their perceptions during the science tasks. Although the students rated the social studies unit on Ancient Egypt as more interesting than the science unit on Light, they were more likely to recall their activities, perceptions and thoughts from the science unit.

In reporting the data in this study, I have made much more use of direct quotations from the students interview responses than has been the case in other research studies. One reason for this is that the results of this study are significantly different from the results the other published studies. As I indicated in the first part of this report, most previous studies focused on students' use of cognitive and metacognitive strategies. Their reports classify the students responses within a "mediational paradigm" in which cognitive and metacognitive strategies are said to mediate between instructional stimuli and achievement outcomes. This paradigm limits the way students' responses are described and reported and the results reflect this limitation.

In this study, the purpose was much more open-ended. We wanted to know what students were thinking when they engaged in classroom activities at those moments when we predicted, on the basis of our model, that they were processing an experience or information that contributed to

their learning of a specific concept or proposition. The result is evidence of a range of different responses that do not look like either specific cognitive or metacognitive strategies.

Relationship of the results to the model of knowledge acquisition

The first point to note in trying to relate the results of this study to our model of knowledge acquisition is that there is little clear evidence of the kinds of processes that we have suggested go on in the long-term working memory. For example, although it is clear that on occasions the students connected their immediate experience to prior knowledge or beliefs (see categories 2.6 and 2.8 in Table 3 above), their is no direct evidence of this taking place as a frequent or necessary part of the way they dealt with their experiences. What does emerge is a picture of students primarily engaged in managing the requirements of tasks. Reported activities, thoughts, feelings are all part of this management process.

This leads to the conclusion that if we are right about the processes that take place in long-term working memory (on the evidence from classroom observations, recordings of their spontaneous talk, and their descriptions of the nature of their knowledge), then stimulated recall interviews do not provide access to those processes. Either they are not accessible to conscious awareness, or awareness is so fleeting that it is forgotten before stimulated recall can recover that awareness.

It seems unlikely however that these processes, if they did occur and were consciously experienced, would have been forgotten. Other details of the students' experiences that were equally transitory (such as what someone said) were not forgotten. In fact the use of the video-clips as memory cues produced surprisingly detailed recall of many different aspects of the students' experiences many days after the event.

There are two possible interpretations that fit the data. The first is that we have been mistaken about the processes that go on in long-term working memory. There are other processes that possibly lie hidden in the video-cued interview data, that we should be identifying. The second is that these processes do occur but students are rarely, if ever, aware of them happening.

In a previous article I have set out the evidence for the set of sociocognitive activities/processes listed above (Nuthall, in press, b). It comes from the ways students talk about and use the knowledge they have acquired, and from our observations and recordings of their experiences and activities. While this evidence is, in many ways, fragmentary and largely

circumstantial, as evidence about mental processes must always be, the amount of agreement between multiple sources of evidence strongly suggests that some set of processes, like those listed, must be involved. When students, for example, recall knowledge that shows an integration of new information with previously held beliefs, it is hard to escape the conclusion that some kind of integration process has occurred. What cannot be inferred from this evidence is when or how the integration process occurred. Two possibilities suggest themselves. One is that the integration does not occur at the time the new information is encountered in the classroom. It occurs at some later time, perhaps only at the time when recall is required. This implies that almost all experiences are stored in memory in some form, available for interpretation, integration, and so on, whenever they are needed. The other is the second interpretation suggested above, namely that processes like integration do go on at the time of the new information is encountered, but unconsciously and automatically, perhaps as a consequence of cognitive routines that have over-learned in the past.

The evidence from the interviews in this study is not incompatible with either of these interpretations. Students do store multiple aspects of their experiences. The can recall details of what they were doing, what others were doing, what they perceived and what they expected to perceive, what they thought and what they previously thought, where their ideas came from, and what they expected to happen next. They can also recall their sense of confusion, or not knowing what to do next, of wondering why, of enjoying and being bored. Not all of these aspects will be stored with each experience because not all were experienced at the time. But there were many instances in the data when students provided surprisingly detailed and complex recall.

This suggests that for as long as these complex memories exist, the students' minds contain a multilayered storehouse of potentially relevant information. The interviews give the impression that more often than not students act and perceive rather than reflect and interpret.

Other data from the interviews suggests that students also store the results of incomplete thinking processes. They reported wondering why something happened without attempting to resolve the query. They reported being puzzled without feeling the need to deal with the sense of puzzlement. In addition, there were occasions when viewing the video-clip not only reinstated the original experience but also the thinking that had been going on at the time. Although not frequent, these occasions support the general impression that finding explanations and resolving doubts is

something that occurs when the need arises rather than at the time of the original experiences. The thinking that does occur during classroom activities is about planning, deciding, agreeing, getting and managing resources, getting written reports finished. Even when the teacher-set task requires an answer to a why question, asking someone else for the answer in order to get the task completed takes precedence over thinking through the answer for oneself.

The other explanation, that is not incompatible with the first, is that the sociocognitive activities/processes that constitute the long-term working memory are almost entirely unconscious. They cannot be recalled because they were never part of the students' awareness. This explanation is consistent with the view that these cognitive processes are an internalisation of the cognitive aspects of the habitual or well-practised activities that constitute classroom life. They are, as it were, the cognitive component of these activities, necessary to their effective management, but not normally experienced independently from, or in a different way from, the experience of the activity itself.

Implications for the model and for the design of classroom tasks.

At the time of writing this draft report, it is not at all clear how to incorporate the results of this study into our model of how students learn from their classroom experiences, nor what the implications are for the design of more effective classroom tasks. The results are not those that were expected. They do not sit easily with the way we have developed the model so far, nor with more traditional cognitive and information processing views of classroom learning. I suspect that we need a better analysis of how students experience and understand their involvement in classroom activities than we have yet been able to achieve. We intend to persist with the use of stimulated recall to explore further with other students in other contexts, how students understand and recall their classroom experiences. This may well mean reconceptualizing our understanding of how students acquire knowledge from their classroom experiences.

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Appendix: Types of student responses to video-clips.

1. Student recalls activities, behaviours, experiences, perceptions

1.1 Recalls what was happening, what the student or others did. Includes describing the sequence of events that made up an activity, what they were supposed to do, what happened.

1.2 Recalls the outcome of an activity, or both what was done and what the consequence or result of the activity was. Includes descriptions of discussions and what was concluded.

1.3 Recalls what the student or others have said or heard. This includes recalling what the teacher said to the class, what the student said to the teacher or other students

1.4 Recalls what the student or others saw or experienced. This includes recalling personal observations and perceptions arising from classroom activities, and from looking at pictures and diagrams

2. Student recalls what she/he was thinking about, or the outcomes of thinking

2.1 Recalls a specific interpretation or elaboration of something that was said or read

2.2 Recalls the process by which a decision was made, how something was planned, solved, or resolved

2.3 The student recalls feeling puzzled, surprised, or wondering about something.

2.4 Recalls the reasons, things considered, or actions taken, when making a decision or reaching a conclusion

2.5 Recalls a lack of relevant knowledge, or a concern or sense of confusion. Includes a sense that there is a problem that needs solving.

2.6 Recalls previous ideas, beliefs before learning or acquiring new knowledge, recalls the source of an idea or information.

2.7 The student recalls the purpose of an activity, what she/he was intending or trying to do, what she/he thinks the teacher's purpose might have been.

2.8 Recalls associations and connections with other knowledge, other experiences

2.9 Recalls the content of her/his thoughts at the time of the activity or event in the video-clip.

2.10 The student is specifically asked to recall thinking and cannot recall anything.

3. Student recalls what she/he was feeling at the time of the video-clip.
Includes descriptions of feeling frustrated, bored, interested, and descriptions of feelings about self, self-evaluations.
3.1 Recalls reactions to the teacher's actions, instructions, comments, or help.
3.2 Recalls the effects of other students
3.3 Student reflects on own ability, likes and dislikes, difficulties
3.4 Recalls affective reactions to objects, events, activities.

4. Thinking during the interview.
During the process of talking with the student in the interview, the student solves a problem of works out an explanation, unprompted.

Table 1 Ages and Listening and Reading Comprehension percentile scores for each selected student in the four studies (W7, C8, W9, and C10).

Topic of unit and hours of recorded time per student	Students (gender)	Age (years)	Percentile for age scores: Listening Comprehension	Percentile for age scores: Reading Comprehension	Class level
W 7. Social Studies topic:	Alice (f)	10.7	71	65	6
Ancient Egypt	Jerry (m)	9.10	59	87	5
(10 hours 17 mins	Kent (m)	10.0	30	19	6
over 8 days)	Verity (f)	9.5	30	25	5
C 8. Social Studies topic:	Amity (f)	10.5	34	30	6
Ancient Egypt	Dean (m)	10.0	44	25	5
(13 hours 9 mins	Julie (f)	9.9	53	70	5
over 8 days)	Kirk (m)	10.5	87	75	6
W 9. Science topic:	Austin (m)	10.9	79	90	6
Light	Karin (f)	10.11	34	94	5
(7 hours 26 mins	Shaun (m)	9.9	50	42	5
over 8 days)	Sonya (f)	11.1	33	19	6
C 10. Science topic:	Eleanor (f)	11.4	91	98	6
Light	Jordan (m)	10.3	74	35	5
(8 hours 52 mins	Seth (m)	11.2	53	19	6
over 6 days)	Sylvia (f)	9.8	67	15	5

Table 2. Characteristics of the video-clips used in the interviews.

Teacher	Student	Class to interview delay (Days)	Video clips	Class days included	Responses coded
W7	Alice	35	28	1	26
	Jerry	35	28	1	25
	Kent	32-34	23	2	31
C8	Amity	21-22	34	2	33
	Dean	21-24	41	3	37
	Julie	22-23	18	3	17
	Kirk	16-17	21	2	26
W9	Austin	16-22	34	4	51
	Sonya	15-20	22	2	27
C10	Eleanor	1-8	28	3	36
	Jordon	2-9	42	3	46
	Seth	3-10	49	4	63
	Sylvia	2-9	33	3	51

Table 4. Relative frequency of recall of cognitive, affective, perceptual and other experiences, activities, and processes as a function of time delay (percent of all responses for each time delay).

	Time delay in days					
	1-4	8-10	15-17	20-24	32-35	Total
	Science units (W9, C10)					
1. Affective experiences	9.8	9.4	5.6	0		7.0
2. Thinking processes	13.8	37.5	33.3	20.4		20.3
3. Products of thinking processes	11.4	12.5	22.2	29.6		16.7
4. Perceptions and experiences	21.1	6.3	0	16.7		16.3
5. Activities and behaviours	31.7	25.0	11.1	25.9		27.8
6. Inability to recall activities, behaviours	3.3	6.3	16.7	5.6		5.3
7. Inability to recall thinking	8.9	3.1	11.1	1.9		6.6
	Social Studies units (W7, C8)					
1. Affective experiences			30.8	8.6	27.9	18.7
2. Thinking processes			7.7	7.1	18.6	10.8
3. Products of thinking processes			19.2	8.6	18.6	13.7
4. Perceptions and experiences			11.5	4.3	0	4.3
5. Activities and behaviours			23.1	48.6	16.3	33.8
6. Inability to recall activities, behaviours			3.8	17.1	11.6	12.9
7. Inability to recall thinking			3.8	5.7	7.0	5.8

Table 3. The frequency of the different types of student responses during the video-cued interviews

Type of student response	Social studies W7	Social studies C8	Science W9	Science C10	Total No.	Total %
1. Activities and perceptions						
1.1 What happened, was done	20	16	14	28	78	16.6
1.2 Outcome of activity	2	1	5	16	24	5.1
1.3 What was said, heard	8	17	6	11	42	9.0
1.4 What seen, experienced	2	13	4	16	35	7.5
1.5 Cannot recall activity, experience	5	13	6	6	30	6.4
Total	37	60	35	77	209	44.6
2. Thinking and outcomes of thinking						
2.1 Interpretation or elaboration	1	1		4	6	1.3
2.2 Deciding, planning, solving	6	2	8	9	25	5.3
2.3 Puzzled, surprised, wondering	2	3	3	10	18	3.8
2.4 Reasons, things considered	5	4	6	19	34	7.2
2.5 Confusion, lack of knowledge	2	3	5		10	2.1
2.6 Previous beliefs, origins of ideas	4	6	2	16	28	6.0
2.7 Identifying purpose, intentions	2	5	7	9	23	4.9
2.8 Connections to other experiences	1			6	7	1.5
2.9 Content of specific thoughts	1	5		15	21	4.5
2.10 Failure to recall thinking	3	4	2	8	17	3.6
Total	27	33	33	96	189	40.3
3. Feelings and self-evaluation						
3.1 Reactions to teacher behaviour	5	1		1	7	1.5
3.2 Reactions other students	4	3	1	3	11	2.3
3.3 Own ability, likes, difficulties	3	10	7	11	31	6.6
3.4 Reactions to objects, events	6	6		6	18	3.8
Total	18	20	8	21	67	14.3
4. Thinking during interview						
4.1 Identifying an explanation			2	2	4	0.9
Total	82	113	78	196	469	

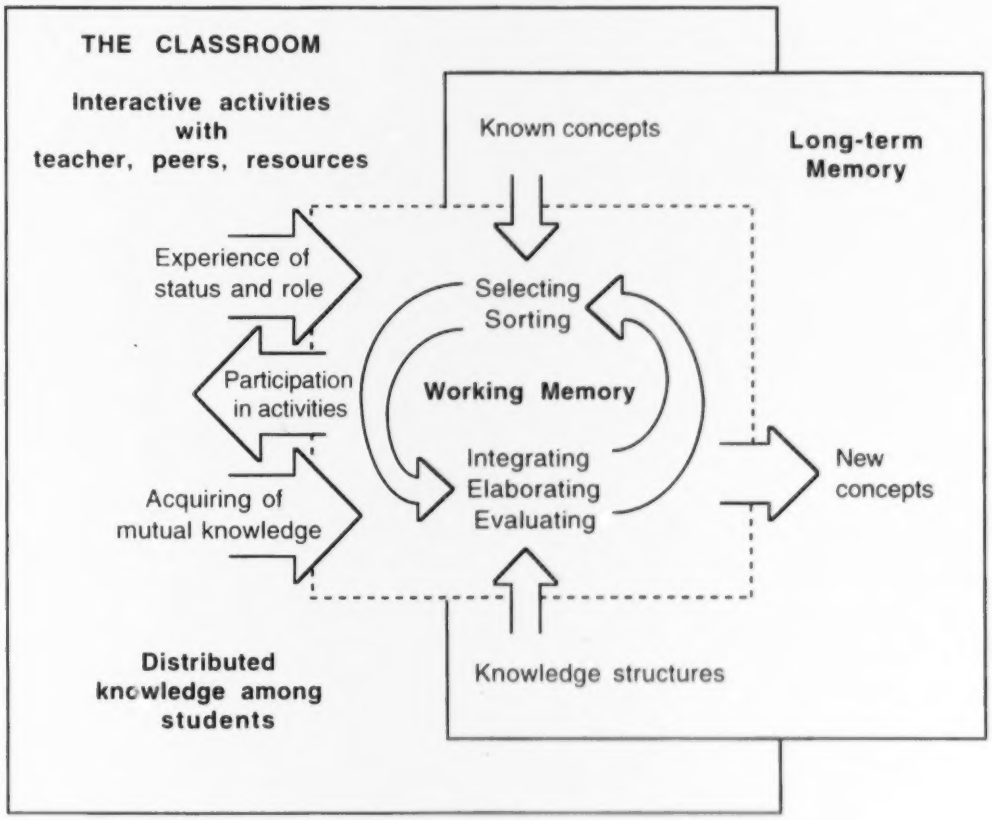

Figure 1. The model of how students acquire knowledge and concepts from their classroom experiences in science and social studies units

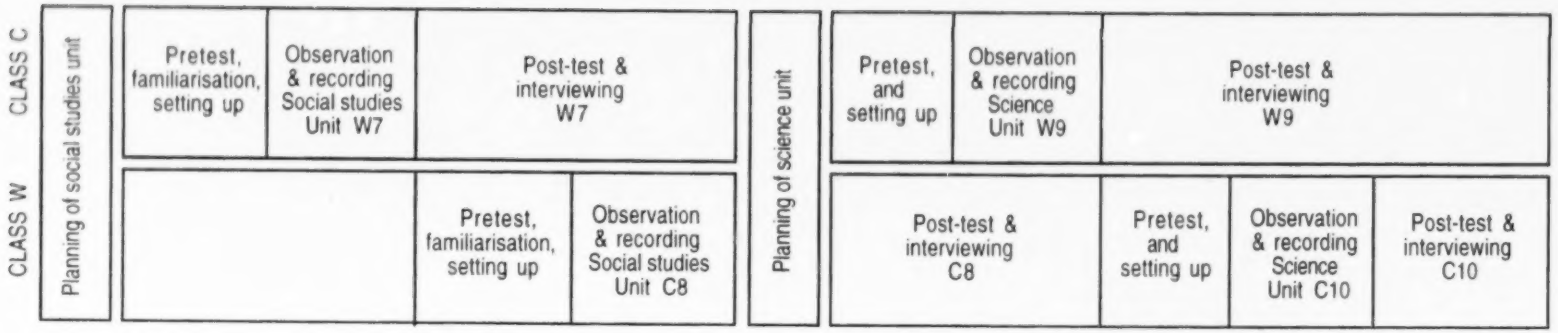
CLASS C
CLASS W
Planning of social studies unit
Pretest, familiarisation, setting up
Observation & recording Social studies Unit W7
Post-test & interviewing W7
Pretest, familiarisation, setting up
Observation & recording Social studies Unit C8
Planning of science unit
Pretest, and setting up
Observation & recording Science Unit W9
Post-test & interviewing W9
Post-test & interviewing C8
Pretest, and setting up
Observation & recording Science Unit C10
Post-test & interviewing C10

Figure 2. The sequence of planning, pretesting, observing, and post-testing and interviewing in the two classrooms with teacher W and teacher C, from August through December.